EXHIBIT A

MATERIALS TECHNOLOGY SERIES

Porous Materials

Process technology and applications

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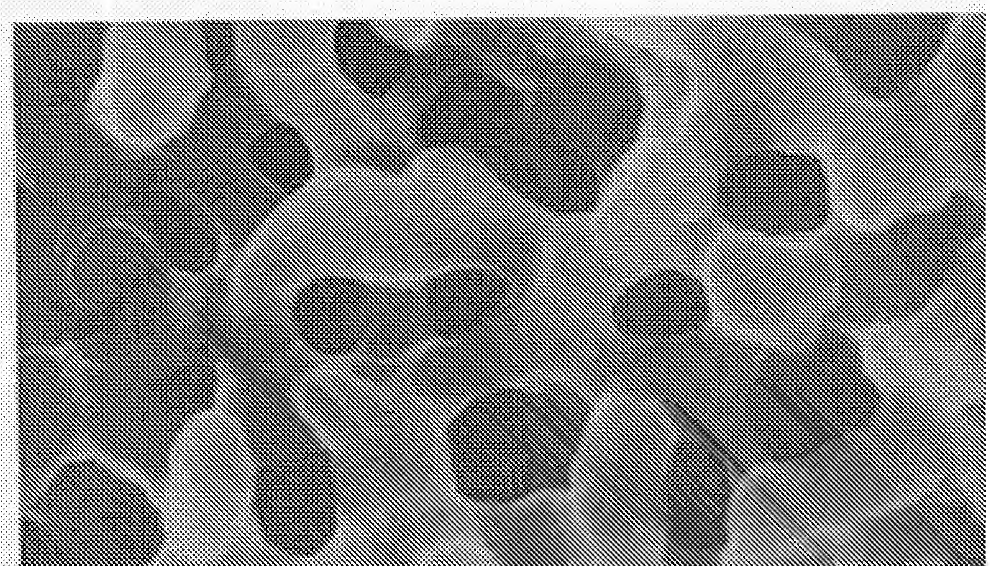

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water by using porous materials of pore size 0.1–100 μm, depending on the size of particles to be removed. Porous materials with micron-scale pores are often made by sintering.

Nowadays, ecological problems and energy-saving efforts are keen industrial issues. The design of industrial processes may be improved in order to overcome these issues, but these design improvements have unavoidable limitations. More improvement of processes can be achieved by developing and improving the materials used in the processes. In the case of filtration of high temperature gas, ceramic filters can be used at higher temperatures than metallic ones. Engineering design will inevitably be changed if new materials are used, as occurred in electronics owing to the introduction of semiconductors.

Recently porous ceramics have been developed with high-temperature stability, strength, catalytic activity, erosion resistance and corrosion resistance. These excellent properties of porous ceramics make it possible to use them in severe operating conditions, compared with the porous polymers, glasses and metals. In spite of these excellent properties, the potential of porous ceramics has not been fully realized because of their well-known problems [2]. These include:

1. brittleness,
2. absence of integrated materials and manufacturing system,
3. lack of pore size control,
4. lack of continuous processing methods,
5. use of processing/sintering aids that limit toughness,
6. absence of joining technologies, and
7. absence of a model relating pore structure to mechanical properties.

Problems 1, 2, 4, 5 and 6 are also applicable to dense ceramics. To overcome these difficulties, researchers of porous ceramics have to approach scientifically the technological problems of materials, from powder production of raw materials to quality control of final products.

1.2 CLASSIFICATION OF POROUS MATERIALS

Many porous materials have been used in many applications. They can be classified by different criteria such as pore size, pore shape, materials and production methods. Classification by pore size and by pore shape is useful in considering applications of porous materials.

Figure 1.3 shows the relationship between pore size and applications of porous materials, and is based on the reports by Chan and Brownsten [3] and Yamamoto [4]. Note that a remarkably wide range of pore sizes from atomic size to millimeters is required in applications of porous materials. These

TABLE 1.2 Different configurations of pore morphology and different production methods of porous materials

	a	*b*	*c*	*d*	*e*	*f*	*g*
Class	Foam	Interconnected	Opening among particles	Opening among plates	Opening among fibers	Large–small pore network (i)	Large–small pore network (ii)
Pore morphology (Figure 1.5)	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Open porosity	Very high	High	Controllable	High	High	High	High
PSD[a]	Wide	Very narrow	Narrow (controllable)	Narrow (controllable)	Wide	Wide	Wide
SSA[b]	Small	Small	Large	Large	Small	Large	Large
Tortuosity	Low	Low	High	Controllable	Low	High	Smooth (depending on large pore network)
Mechanical strength	Low	High	High	Low	High	High	Low
Production methods	Applying foaming agent or surfactant Applying polymer foam	Leaching process Sintering compact with low density	Sintering powder compact	Sintering powder compact	Sintering fiber compact Leaching process	Sintering powder compact with pore former Sintering powder compact with agglomerated or porous particles	Activated carbon Sintering powder compact with agglomerated or porous particles
Remarks	The highest open porosity	Smooth surface and homogeneous PSD	Pore shape and porosity are controllable	Porosity becomes small if plates pile up		Bimodal PSD	Bimodal PSD

[a] PSD pore size distribution.
[b] SSA specific surface area per unit volume

EXHIBIT B

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Emulsion Templating

Emulsions are heterogeneous mixtures of at least one miscible liquid dispersed in another in the form of droplets. In most cases, at least one of the liquids will be water or an aqueous solution. An emulsion is often described as either oil-in-water (O/W) or water-in-oil (W/O) where the first phase mentioned refers to the internal (or dispersed) phase. In the context of polymer synthesis, emulsions can be used in three ways (Fig. 1) as "templates" for the preparation of colloids, porous materials, and composite materials, respectively. Emulsion templating is a flexible and easily-controlled method for the fabrication of macroporous materials (pore size range 5–100 μm) by polymerising the continuous phase of a high internal phase emulsion (HIPE) (internal phase volume > 74.05 %). If a less concentrated emulsion is used (internal phase volume < 60 %), a more closed-cell porous structure will be obtained.

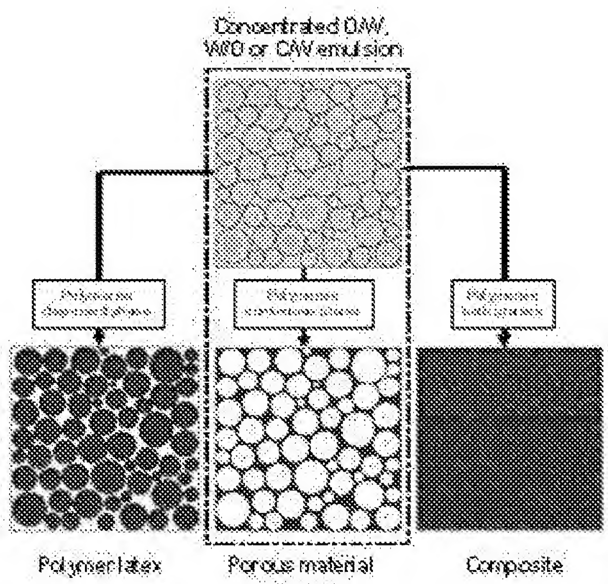

Figure 1

In our research, high internal phase oil-in-water (O/W) emulsions are used to prepare hydrophilic polymeric materials. It is then extended to make hiearically porous inorganic materials (such as silica, alumina, zirconia, titania), metals (such as gold, palladium), and site-isolated nanocomposites (such as gold nanoparticles in silica). To avoid the use of a large amount of organic solvents in the emulsion, compressed CO_2 has been used to produce the emulsions and porous structures. We have also developed hydrocarbon surfactants to stabilize CO_2-in-water emulsions with the volume ratio of CO_2 phase up to 90 %. As a result of these stable CO_2 emulsions, highly porous polyacrylamide and poly(vinyl alcohol) have

been prepared. Below gives a few images of emulsion-templated porous materials.

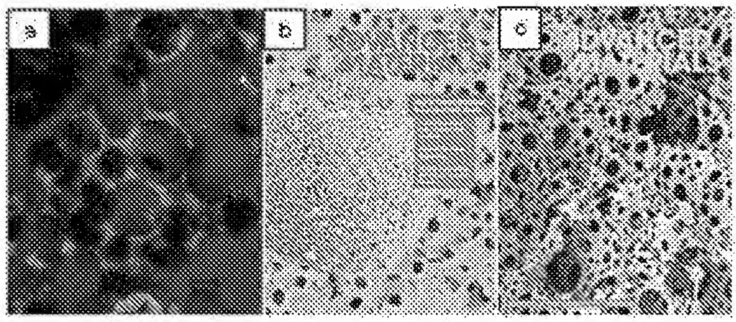

Figure 2: (a) Porous silica structure, scale bar 20 µm; (b) Emulsion-templated gold beads; (c) Porous polyacrylamide made from CO_2-in-Water emulsion